Dynamic weight analysis of risk index during earth-rock dam construction

LI Zongkun[a], LI Qi[b]

School of Zhengzhou, Zhengzhou University, Zhengzhou 450001, China.

[a]Lizongkun@zzu.edu.cn, [b]Liqzzu@163.com

Keywords: Dynamic weight; uncertain type of AHP; Expert's credibility; Risk analysis

Abstract. There are two shortages of traditional AHP method: (a) expert scoring to be absolute and (b) less considering the credibility of expert scoring and the dynamic difference between experts. In order to solve the above-mentioned drawbacks, an uncertain type of AHP method based on expert's credibility is proposed in this paper. Risk index dynamic weight calculation model is established. In this method, when the expert scores, they use the interval number instead of a specific value to represent the expert judgments. Determine the degree of the experts' credibility according to the similarity and difference between the uncertain type of matrix. At the same time, considering the subjectivity and objectivity of the index weight, determine the dynamic weight. Example analysis shows that this method is reasonable and feasible, and the dynamics weight can reflect the engineering practice.

1. Introduction

Earth rock-fill dam construction period generally has the characteristics of long duration, complex environmental factors, bad operating conditions and so on. Compared with the operation period, the construction period can be influenced more easily. In this period, the structural stability is relatively poor, and there are many risks predisposing conditions. Therefore, it is very important to evaluate the risk of earth rock-fill dam construction period, and it has important significance for the smooth implementation of engineering construction and the safe operation of the late period.

AHP used as a comprehensive evaluation method, is to solve the scheduling problem of multi factors. At present, expert often use the scale method of 1-9 to mark. Although it provides a feasible way to determine the weight of multiple factors, there are still some shortcomings. On one hand, traditional AHP method use 1-9 scale method to compare the importance of two factors with an accurate number. But, because of the complexity of risk factors, fuzziness of information and the limitation of experts' knowledge, experts can not make absolutely accurate judgments. Therefore, traditional method of AHP will lack the maneuverability, and can not reflect the real engineering. On the other hand, the risk analysis of Earth rock-fill dam construction period is a group decision process. There are many experts participate in. But due to the difference of engineering experience, knowledge reserves and the engineering information between different experts, the risk weight determined by experts are different. But the risk weight based on the reputation is a static weight and subjective weight. This weight can not objectively reflect the awareness degree of decision problem.

2. Dynamic weight calculation model of risk index

Firstly, we construct the uncertain judgment matrix. Based on the uncertain type of AHP theory, experts are still using the 1-9 scale method in scoring pair wise risk factors important degree. In order to build uncertain judgment matrix, in this process, experts' dynamic weights will be contacted with group decision, and we will determine the confidence level of experts based on the similarity and difference of the judgment matrixes.

2.1 Determination of the reliability of expert

Different experts on the same indicator weights are not the same, but we can determine the confidence level of the experts based on the similarity and variations of uncertain judgment matrixes given by different experts. It assumes that there are number q experts to participate in decision-making. It can be considered that in all of the judgment matrixes, if the similarity degree between the other judgment matrixes is high, then the credibility should be higher, so the role of the group decision should be greater. The similarity is calculated as follows:

$$\gamma_{st} = \frac{\left(vec\left(A_s\right), vec\left(A_t\right)\right)}{\left\|vec\left(A_s\right)\right\| \bullet \left\|vec\left(A_t\right)\right\|} \tag{1}$$

$$\gamma_t = \sum_{s=1, s \neq t}^{q} \gamma_{st} \tag{2}$$

$$\lambda_t = \frac{\gamma_t}{\sum_{t=1}^{q} \gamma_t} \tag{3}$$

In the formula： A_s, A_t , Refer to the judgment matrixes given by two experts; $\gamma_{st}=\cos\alpha st$, refer to the angle of vec(A_s) and vec(A_t), means the similarity of A_s and A_t; γ_t, Refer to the sum of the similarity with other judgment matrices; λ_t, Refer to the similarity between the first expert judgment and other experts' judgment after the normalization process.

2.2 Determination of the difference of the uncertain judgment matrixes

As with the same degree of similarity, the degree of difference can be reflected from the other aspects of the evaluation of the confidence of experts, as follows:

$$\sigma_t = \sum_{j=1}^{2n^2} \left| a_{tj} - \frac{1}{q} \sum_{i=1}^{q} a_{ij} \right|, \quad \left(t = 1, 2, \cdots, q\right) \tag{4}$$

$$\delta_t = \frac{\sigma_t}{\sum_{t=1}^{q} \sigma_t}, \quad \left(t = 1, 2, \cdots, q\right) \tag{5}$$

In the formula: a_{tj}, Refer to the elements of uncertain judgment matrixes given by experts;σ_t refer the sum of the difference with other judgment matrices;δ_t refer the difference between the evaluation of the first experts and other experts after the normalization process.

2.3 Determination of the confidence of experts

Based on the similarity and difference of the decision of the experts, the experts' confidence level is determined. Regard the similarity and difference as two variables. Then, with the expert's judgment matrixes are different, the expert's confidence is also different. That means the expert’s weight is dynamic. Determination of the degree of confidence of experts as follows:

$$r_t = \begin{cases} \lambda_t, & \sum_{i=1}^{q} \lambda_i \bullet \delta_i = 1 \\ \dfrac{\lambda_t \left(1 - \delta_t\right)}{1 - \sum_{i=1}^{q} \lambda_i \bullet \delta_i}, & \sum_{i=1}^{q} \lambda_i \bullet \delta_i \neq 1 \end{cases} \quad (t = 1, 2, \cdots, q) \tag{6}$$

2.4 Calculate the finall weight of the Index

At present, there are 10 kinds of methods to calculate the weight of the uncertain judgment matrix. For example, the interval number method (IME), interval number of generalized gradient feature vector method(ICGEM), interval number of logarithmic least squares method (ILLSM) and the optimal transfer matrix method. Among them, the number of interval numbers is applied widely, and is reasonable.The weight of the uncertain judgment matrix as follows:

$$\omega_{i1}=\frac{1}{2}\frac{\sum_{t=1}^{q} r_t\left[\left(u_2^t\right)^2-\left(u_1^t\right)^2\right]}{\sum_{t=1}^{q} r_t\left[\left(u_2^t\right)-\left(u_1^t\right)\right]} \quad (8)$$

$$\omega_{i1}=\frac{1}{2}\frac{\sum_{t=1}^{q} r_t\left[\left(u_2^t\right)^2-\left(u_1^t\right)^2\right]}{\sum_{t=1}^{q} r_t\left[\left(u_2^t\right)-\left(u_1^t\right)\right]} \quad (9)$$

$$\omega_i=\frac{\omega_{i1}\bullet\omega_{i2}}{\sum_{i=1}^{q}\omega_{i1}\bullet\omega_{i2}},\quad \left(i=1,2,\cdots,n\right) \quad (10)$$

2.5 Establish the risk assessment model of earth rock-fill dam

There are a number of projects during the Earth rock dam during construction period, this paper take the dam engineering as an example. Considering the possible risk, on the basis of the existing risk classification, this paper mainly consider risk of natural factors and economic fluctuation, and then combine with the characteristics of uncertainty and level, set up the risk evaluation model of earth rock dam during construction period filling engineering. See Figure 1

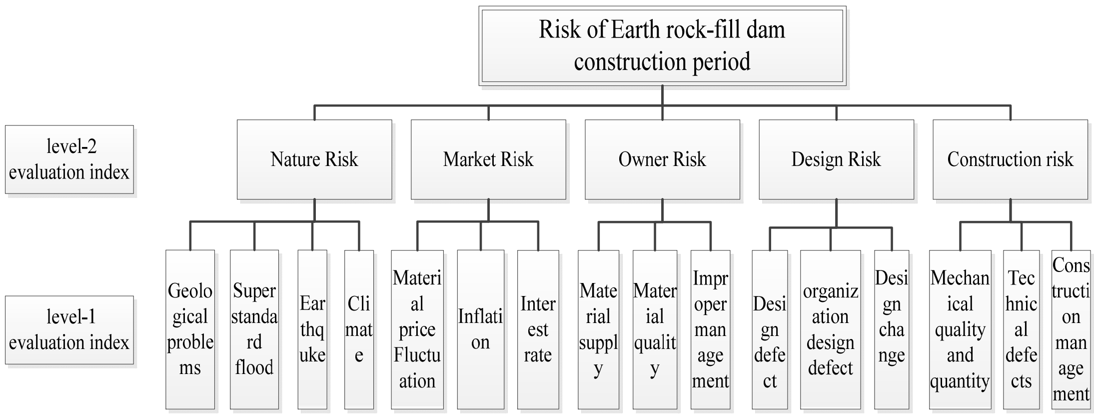

Fig.1 Risk evaluation model of Earth-rock Dam during construction period

3 Result

Combined with the above model, invited four engaged in water conservancy engineering design experts, using scores, uncertain AHP methods to establish uncertain-weight judgment matrix. Second, according to the risk dynamic weighting model, to deal with uncertain-weight judgment matrix, and USES the MATLAB and Excel respectively risk weighting interval expert confidence level, each layer are calculated and the dynamic weight each risk index. The results are shown in table 1 to table 6 (the calculation process is abbreviated)

Table 1 The dam filling risk weights

Experts	Experts confidence	The dam filling risk weight interval				
		R_1	R_2	R_3	R_4	R_5
A	0.2547	[0.1472,0.1573]	[0.0840,0.0873]	[0.1030,0.1086]	[0.2840,0.3029]	[0.3554,0.3703]
B	0.2462	[0.1506,0.1556]	[0.0715,0.0732]	[0.1056,0.1097]	[0.2948,0.3060]	[0.3608,0.3722]

C	0.2488	[0.1295,0.1369]	[0.1210,0.1265]	[0.0778,0.0809]	[0.2960,0.3098]	[0.3508,0.3709]
D	0.2503	[0.1407,0.1505]	[0.0947,0.0986]	[0.1010,0.1064]	[0.2779,0.2945]	[0.3573,0.3784]
Comprehensive weight		0.145	0.101	0.095	0.293	0.366

Table 2 Natural factors risk weights

Experts	Experts confidence	Natural factors risk weight interval			
		R_{11}	R_{12}	R_{13}	R_{14}
A	0.2311	[0.2202,0.2355]	[0.3248,0.3378]	[0.2590,0.2643]	[0.1775,0.1809]
B	0.2492	[0.2073,0.2233]	[0.3169,0.3346]	[0.2872,0.2960]	[0.1677,0.1715]
C	0.2465	[0.1975,0.2009]	[0.3234,0.3331]	[0.2790,0.2867]	[0.1827,0.1966]
D	0.2732	[0.2006,0.2030]	[0.3350,0.3474]	[0.2882,0.2947]	[0.1614,0.1703]
Comprehensive weight		0.215	0.328	0.281	0.176

Table 3 Market economy factors risk weights

Experts	Experts confidence	Market economy factors risk weight interval		
		R_{21}	R_{22}	R_{23}
A	0.2518	[0.7041,0.7432]	[0.1547,0.1887]	[0.0982,0.1181]
B	0.2442	[0.6580,0.7305]	[0.1353,0.1681]	[0.1307,0.1984]
C	0.2487	[0.6178,0.6900]	[0.1552,0.2020]	[0.1490,0.2048]
D	0.2553	[0.6213,0.6931]	[0.2078,0.2278]	[0.1009,0.1751]
Comprehensive weight		0.672	0.175	0.153

Table 4 The owner factors risk weights

Experts	Experts confidence	The owner factors risk weights interval		
		R_{31}	R_{32}	R_{33}
A	0.2683	[0.3705,0.3922]	[0.3527,0.3698]	[0.2538,0.2609]
B	0.2673	[0.3715,0.3932]	[0.3517,0.3688]	[0.2538,0.2609]
C	0.2401	[0.3630,0.3938]	[0.3660,0.3915]	[0.2381,0.2477]
D	0.2244	[0.3912,0.4112]	[0.3204,0.3425]	[0.2632,0.2714]
Comprehensive weight		0.385	0.256	0.359

Table 5 The designer factors risk weights

Experts	Experts confidence	The designer factors risk weights interval		
		R_{41}	R_{42}	R_{43}
A	0.2515	[0.4803,0.4979]	[0.3023,0.3149]	[0.1974,0.2073]
B	0.2320	[0.4020,0.4313]	[0.3342,0.3524]	[0.2232,0.2468]
C	0.2617	[0.4803,0.4979]	[0.3223,0.3349]	[0.1774,0.1873]
D	0.2636	[0.4193,0.4502]	[0.3189,0.3369]	[0.2273,0.2473]
Comprehensive weight		0.450	0.328	0.222

Table 6 Contractor risk factors weights

Experts	Experts confidence	Contractor risk factors weights interval		
		R_{51}	R_{52}	R_{53}
A	0.1975	[0.3432,0.3575]	[0.3035,0.3132]	[0.3348,0.3478]
B	0.2802	[0.2913,0.3085]	[0.4065,0.4258]	[0.2769,0.2946]
C	0.2452	[0.3040,0.3157]	[0.3852,0.3985]	[0.2934,0.3031]
D	0.2771	[0.2925,0.3007]	[0.3671,0.3773]	[0.3250,0.3374]
Comprehensive weight		0.310	0.382	0.308

4 Summary

This article will introduce the concept of similarity and difference of judgment matrix into the expert weight. Determine the expert confidence based on the similarity and difference of uncertain judgment matrix. The same expert gives the different judgment matrix, and the confidence of expert is also different. So the weight of expert is dynamic. So the weights of risk factors are also different. In this way, the weight calculation is more scientific and rational. At last, it will built a good foundation for further overall risk assessment.

References

[1] LI Zongkun, GE Wei , Wang Juan .Etal. Improved catastrophe theory evaluation method and its application to earth-rock dam risk evaluation during construction [J]. SHUILI XUEBAO, 2014 , 5(10): 1256-1260.

[2] SONG Xiaobo, CAI Xin, YANG Jie. Fuzzy comprehensive Evaluation of Sluice safety Based on Improved AHP Method [J]. Water Resources and Power , 2013, 31(2): 174-176.

[3] LU Mou ,WANG Ji Liang, ZHANG Hongguo.Comprehensive safety assessment method for water supply network in urban area [J].SHUILI XUEBAO,2009,40(12):1489-1494.

[4] JIN Juliang,WEI Yiming,DING Jing.Fuzzy comprehensive Evaluation model based on improved analytic hierarchy process [J].SHUILI XUEBAO,2004,(3):65-70.

[5] CAO Wengui,ZHAI Youcheng,WANG Jiangying, etal.Method of Set Pair Analysis for C ollapse Risk During Construction of Mountain Tunnel [J].China Journal of Highway an d Transport , 2012 , 25(2):90-98.

[6] Kwai-Sang Chin,Dong-ling Xu,Jian-Bo Yang.Group-based ER-AHP system for product project screening [J].Expert Systems with Application,2008,35(4):1909-1929.

[7] MA Zhongjun，DENG Ting, WANG Shijie . Improved analytic hierarchy process based design for safety evaluation system of Donghai Bridge [J].Water Resources and Hydropower Engineering, 2011 ,42(1):85-88.

[8] Huang Q, Ren Yuan, Lin Yang.Application of uncertain type of AHP to condition assessmentof cable-stayed bridges [J].Journal of Southeast University (English Edition),2007,23(4):599-603.